but, on the contrary, that the possession of a closed tracheal system is a secondary condition, derived from ancestors provided with spiracles.

He adopts the view that the existing insects are derived from an ancestor, in which the larvæ resembled the existing genus Campodea, with a hemimetabalous metamorphosis, and an open tracheal system; and he dwells on the important fact that in Campodea each spiracle has an independent set of tracheæ. So also in the course of embryonal development, the tracheal systems rise separately, and then the anterior and posterior branches unite to form the lateral ducts.

In a still earlier stage he thinks it probable that the tracheæ resembled those of the curious genus Peripatus. He observes that the skin-glands of certain worms secrete not only fluid, but also gas (carbonic acid), and from this to an absorbing function would be a comparatively small step. He supposes, then, that the tracheæ are derived from the skin-glands of worms, passing firstly through the stage now represented by Peripatus, in which there are a number of tracheal tubes with numerous scattered openings; secondly, though one represented now by Campodea and certain myriapods, in which the spiracles are situated in pairs, and are connected with separate tracheal systems. I. L.

## *ON THE EVOLUTION OF HEAT DURING MUSCULAR ACTION*[1]

PROF. A. FICK, of Würzburg, in continuing his researches on the source of muscular power, has obtained some new and exceedingly important results, of which the following is a condensed account:—

It is obviously an interesting question in the physiology of muscle what fraction of the work yielded by chemical action in muscular tissue can be employed in overcoming mechanical resistance? the remainder of the chemical work appearing, in all probability, as heat.

Many years ago Helmholtz calculated, from certain considerations, into which, however, there entered several hypothetical factors, that possibly one-fifth of the total work yielded by chemical force in the human body might be employed in muscular action, the remaining four-fifths appearing as sensible heat. From this it necessarily follows that a much larger proportion than one-fifth of the work yielded by chemical force *in the muscle itself* can be employed in overcoming mechanical resistance, inasmuch as it is assumed that a great part of the oxidation takes place in other tissues, where mechanical work is quite out of the question, and where heat alone can be the result.

If, however, thermodynamical experiments show that of the chemical work going on in the muscle only a small fraction, not much exceeding one-fifth, produces mechanical effect; then, supposing the coefficient of Helmholtz to be true, it would be proved that only minute quantities of combustible material are oxidised elsewhere than in the muscles. The author's experiments have been made with a view to answer the first of the above questions—what fraction of the chemical force eliminated in the muscle is used in mechanical work? Such experiments can, of course, with the present means of research, only be carried out upon the muscles of the frog. How far the results obtained are applicable to other classes of animals, is a distinct question.

Thus two magnitudes have to be determined in absolute measure, viz., the mechanical work performed by the muscle, and secondly, the amount of chemical work that the muscle has yielded during the action.

The amount of heat produced in the muscle was of course measured by multiplying the rise in temperature of the muscle by its capacity for heat. In the calculations the specific heat of muscle was taken as equal to that of water. It cannot be greater, and is probably not much less, inasmuch as three-fourths of living muscle are water. The rise in temperature was measured by thermo-electrical means. The galvanometer used had no fixed magnet, and its constancy was proved to extend over many weeks, and even months. The thermopile had to be so arranged that it was as much as possible surrounded by the mass of muscle; its construction will be better understood after the preparation has been described. The gastrocnemius muscle, which is the favourite preparation in such experiments, was replaced by the masses of muscle which pass from the pelvis to the tibia on the inner side of each thigh, whilst the other muscles, with the sartorius and biceps, as well as both the thigh-bones, were removed. Then, on suspending the pelvis, the two prepared masses of muscle hung vertically downwards in intimate contact with each other, all the nerves belonging thereto being easily preserved. One end of the thermopile, with very flat and thin elements, was then placed in the fissure between the two masses of muscle, this arrangement being found by experience to be a perfectly trustworthy one.

A remark is necessary concerning the method of irritating the preparation. Some years ago the author had the opportunity of observing, in some unpublished experiments, that an electric current of sufficient strength to produce the most powerful contraction in a muscle, does not appreciably raise the temperature of the latter. Even with Heidenhain's exceedingly delicate thermopile there was scarcely any evidence of heat being produced in a dead muscle through which a current of twenty-four Daniell's elements was passing for several seconds; and even induction currents of immense strength produced no visible thermal effect. This fact is of great interest in myothermic experiments, as it is thus no longer necessary to impart the stimulus through the nerve, but simply to subject the muscle to direct electrical irritation.

In his experiments, the author has adopted preferentially the method of direct irritation, one of the two copper wires connected with the induction-coil being attached to the pelvis, and the other to the knee of the frog.

The mechanical work was measured by connecting the preparation with one arm of a lever to which a weight was attached, and, in some of the experiments, there were also two balanced weights placed upon the lever to increase its inertia, by which it was found that the work performed was very considerably increased.

The following is a summary of the chief results arrived at by these experiments:—

1. By the interposition of a thin thermopile between suitable masses of muscle, it is possible to determine with great accuracy the absolute amount of heat produced by their contraction.

2. The determination of the muscle-temperature is not interfered with by electrical currents, which, for the purpose of irritation, are passed through the muscle. Therefore direct electrical irritation of the muscle is permissible, and indeed far preferable, in myothermic researches.

3. To the fundamental law of Heidenhain, that a muscle contracting to its greatest extent evolves more heat the greater its initial tension, we may now add that, with equal initial tension, a muscle will evolve more heat if, by means of weights in equilibrium, greater tension be produced during the contraction.

4. A muscle overcoming a greater resistance, works not only with more activity but also with more economy than when occupied in a smaller effort.

5. In an energetic muscular contraction against as great a resistance as possible the eliminated chemical force is about four times as great as the mechanical work it performs. With a less resistance the chemical is a greater multiple of the mechanical force, and with no resistance at all it is obviously indefinitely greater.

6. The amount of heat produced by the eliminated chemical force in an energetic contraction of 1 grm. of

[1] Ueber die Wärmeentwickelung bei der Muskelzuckung," in the *Archiv. f. Physiologie*, Band xvi.

untired frog's muscle is sufficient to raise 3 mgrm. of water from 0° to 1° C.

7. By adopting some very probable assumptions it can be inferred that the combustion of assimilated food, as far as the oxygen inspired is employed in producing chemical force, takes place almost exclusively in the muscular tissues. P. FRANKLAND

## ERNST HEINRICH WEBER

WE are called upon to chronicle the death, at Leipzig, on January 26, of Prof. Ernst Heinrich Weber, whose name is so closely united with the fundamental principles of modern optics and acoustics. He was born at Wittenberg, June 24, 1795, and after having studied at the university of that city received, in 1815, the degree of M.D. Two years later he published a short work on the anatomy of the sympathetic nerves, which brought his name at once into prominence. The following year he was appointed extraordinary professor of anatomy at the University of Leipzig, and in 1821 he became ordinary professor of human anatomy. He was early well known by his edition of Hildebrandt's "Anatomie," of which he wrote anew a considerable part in 1830. The chair of physiology was offered to him in 1840, and he actively fulfilled the duties of this position until a short time before his death. During this period he issued several manuals of physiology, and published a number of investigations, the most valuable of which are gathered together in his book "Annotationes anatomicæ et physiologicæ" (1851). Science is, however, chiefly indebted to Prof. Weber for the classical researches carried out by him and his brother Wilhelm Eduard while still young men, on which is grounded the celebrated wave-theory. The work in which their investigations are recorded—"Die Wellenlehre auf Experimente gegründet" (1825), is a remarkable relation of the most delicate and ingenious observations ever undertaken to establish a series of physical laws. Among the most notable of these might be mentioned the experiments on waves of water in mirrored troughs, by means of which they found that the particles near the surface move in circular paths, while those deeper in the liquid describe ellipses, the horizontal axes of which are longer than the vertical. By another series of comparative observations on water and mercury the law was established that waves moved with equal rapidity on the surfaces of different mediums, while the rapidity increases in both cases with the depth of the liquid. These and a multitude of other facts, studied and elaborated in the most scrupulous and conscientious manner, form the basis for the whole theoretical structure accepted at present as explanatory of the phenomena of light and sound. So thoroughly and scientifically were these researches carried out that subsequent physicists have never been called upon to correct them. In 1850 Prof. Weber completed an extensive series of experiments designed to study the wave-movement in the arterial system and explain the fact that the pulse-beat was felt at the chin a fraction of a second sooner than in the foot. The results showed that the pulse-beat travels with a rapidity of about thirty-five feet per second, and that in general the rapidity of a wave in small elastic tubes is not affected by the increase of pressure on the walls. At a later date Prof. Weber published some interesting results of experiments on the mechanism of the ear, as well as on the microscopic phenomena visible on bringing together alcohol and resin suspended in water in capillary spaces.

## DR. P. BLEEKER

ON January 24 death quite suddenly overtook one of the most indefatigable workers in the field of zoological science, the well-known ichthyologist, Dr. P. Bleeker, who died at his residence in the Hague, at the age of fifty-nine. Born at Zaandam in 1819, he had an early taste for natural history, and studied medicine with a view to an appointment in the army. In 1838 he received an appointment in the medical staff of the East Indian army, and left for Batavia. Here an immense field was soon opened to his activity. He set himself to form an immense collection of fishes from different parts of the colonies, assisted in many ways by a number of his medical colleagues at different stations. He himself always remained at Batavia, gradually rising in his profession till he obtained the inspectorate of the Colonial Medical Service. At the same time he was the centre of a keen scientific movement in the capital of the Dutch Indies, starting several societies and taking the chair in the principal of them for many consecutive years. His contributions to the Indian ichthyological fauna were regularly published in Batavian scientific journals. In 1860 he returned to his native country, and first took up his residence at Leyden, with a view to comparing the treasures contained in the zoological collections there with his own. Extensive consignments of fishes had been made by him to this institution at the time of his residence in Batavia, part of the arrangement and determination of which he now took upon himself. Not long afterwards he went to live at the Hague, where the dignity of Councillor of State Extraordinary was conferred upon him. He set to work at the gigantic task he had undertaken—the publication of his "Atlas Ichthyologique des Indes Orientales Néerlandaises," seven volumes of which, illustrated by several hundreds of coloured plates have appeared. He was herein largely assisted by grants from the Colonial Government. Many important groups, the Gobioidæ, the Scombridæ, the Scorpænidæ, &c., as well as the whole of the Elasmobranchs are left unfinished. He himself estimated that little less than half of the work remained to be published, and latterly had misgivings whether he would really be able to finish it.

The number of separate publications on East Indian fishes which have appeared from his hand in different journals exceed three hundred; they form the basis on which he gradually raised the structure of his Atlas.

He had brought home his large collection of spirit specimens which has always remained in his private possession. Of late years, as he advanced with the publication of his Atlas, he disposed of the specimens of those groups which he had finished; in this way no less than 150 of his unique type-specimens were acquired by purchase by the British Museum. Another disadvantage under which a private collection of these dimensions often labours—and Bleeker's was no exception—is the loss of the exact localities from which the different specimens of one species were procured, a detail which is afterwards of such high importance in determining the geographical range of varieties. Here, however all the specimens are mixed together in one bottle without being separately labelled.

An extensive collection of reptiles and amphibians from the Archipelago, on which he had published several papers during his stay in India, have passed to the British and Hamburg Museums.

## ABOUT FISHES' TAILS

MOST people know the difference in shape that there is between the tail (caudal fin) of a salmon and that of a shark; how in the former the lobes of the fin seem to be equal or symmetrical (homocercal), and in the latter only the lower lobe of the fin is, as it were, developed, and the back bone (vertebræ) of the fish seems to be prolonged into the feebly-developed upper lobe (heterocercal). This remarkable distinction was first of all recognised by Agassiz, and long ago Owen wrote, "the preponderance of heterocercal fishes in the seas of the geological epochs of our planet is very remarkable; the prolongation of the superior lobe characterises every fossil fish of the strata anterior to and including the magnesian limestone; the